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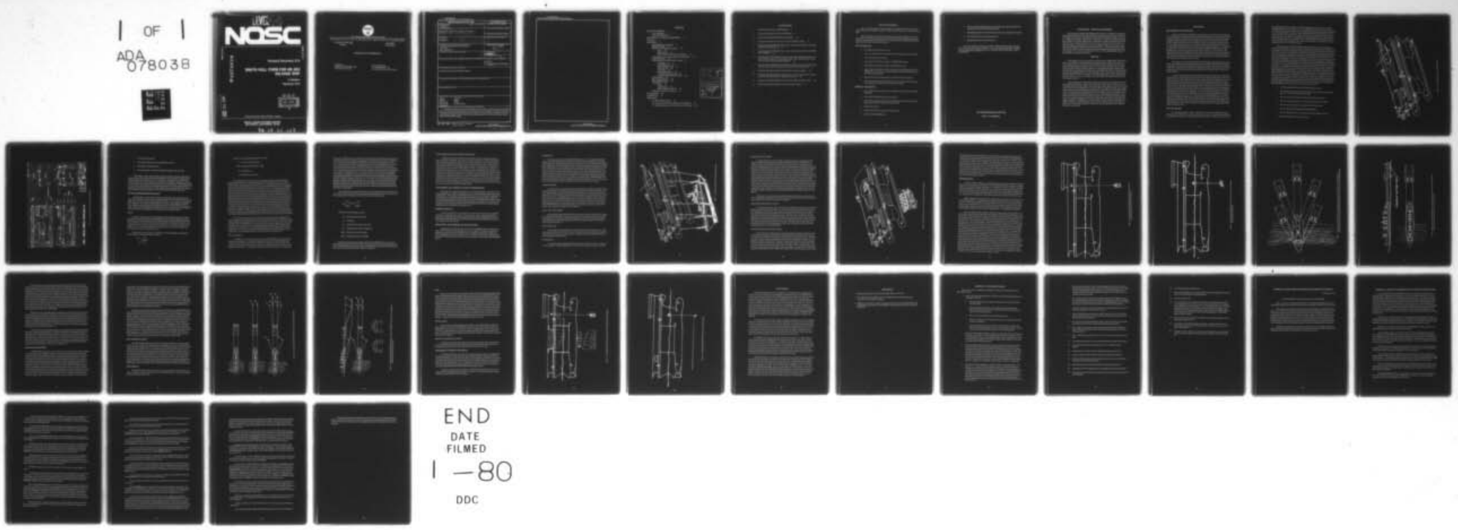

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SWATH HULL FORM FOR AN ARS SALVAGE SHIP

H Chalmers

September 1979

Approved for public release; distribution unlimited

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

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Advances the premise that the new ARS-46 design provides virtually no capability increase over the ARS-38 hulls it is to replace, except increased horsepower. The superior motion characteristics of the SWATH are discussed, and significant motion- and geometry-related capability improvements are identified and developed. Concludes by recommending the ARS-46 design be held in abeyance pending comparisons of functions, capabilities and cost-effectiveness with SWATH concepts.

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CONTENTS

ILLUSTRATIONS

EXECUTIVE SUMMARY

The new ARS-46 design provides virtually no capability increase over the older ARS-38 class hull it is designed to replace, with the major exception of an increase in horsepower.

This paper describes and explains the superior motion characteristics of the semisubmersible, or SWATH, and identifies and develops the following significant motion- and geometry-related capability improvements that a semisubmersible or SWATH-ARS design would provide for this operational requirement.

NEW CAPABILITIES

- Very high sea state operations (to 6).
- Very low motion stress environment for both equipment and personnel.
- Full helo operations and support.
- Universal lift frame (60-ton capacity) for DSRV-SDV support.
- Submersible and equipment hangar for DSRV-SDV support.
- Lower hull lock-in/lock-out hatches with guide rails and handling systems for RUWS, PTC, rescue bell, diver support, SDV and instrumented and/or array and VDS towing operations.
- Bottom-sitting for stranding assistance and inshore salvage operations.
- Very large operational draft range (15 to 45 feet), with an automatic ballast control system to provide a broad operational capability.

IMPROVED CAPABILITIES

- Dual, widely-spread propulsion units for high bollard pulls and wrenching capabilities.
- Very rapid and improved beach gear operations.
- Fore and aft transverse thrusters on both hulls for excellent dynamic stationkeeping with automatic and manual control modes.
- Dual towing winches.
- Excellent high-sea-state transit speed maintenance.
- Static belly lifts (600-800 tons).

- Port and starboard traveling cranes to service the entire ship's deck and peripheral (port, starboard, forward and aft) areas.

- Firefighting assistance with improved means for men and equipment transfers.

- Port, starboard and aft lower sponson decks.

- Multiple salvage and recovery lift points.

The paper concludes recommending that the ARS-46 design be held in abeyance until its basic monohull design undergoes a critical and objective functional, capability and <u>cost effectiveness comparison</u> with the semisubmersible SWATH-ARS concept recommended.

THE SEMISUBMERSIBLE SWATH-ARS

IS NOT A CATAMARAN

BACKGROUND – THE BASE REQUIREMENT

The Operational Requirement (OR) listed as reference 1 establishes a requirement for replacement ships for the six ARS-38 Bolster class salvage ships. It includes a broad set of both general and specific requirements and operational criteria and parameters that call for a highly-maneuverable, long-endurance, all-weather, ice-reinforced towing and salvage vessel capable of providing diving support, submersible support and aviation support for helicopter-hover operations. Further, it must be able to perform all the missions of an ARS with primary responsibilities for harbor and offshore salvage; be able to receive and support certain modular special mission oriented systems; i.e., mixed gas diving, oil pollution cleanup, 2000-foot-deep multi-point moors, ocean engineering, advanced force operations support, etc.; and be able to perform all of these services independently and under both peacetime and wartime conditions.

THE GOAL

Taken together, the above requirements clearly call for a highly adaptive functional and practical design; one suited primarily to support stationary operations; i.e., those in-water operations such as underwater repairs, salvage operations, assisting stranded vessels, tethered systems support, diving operations, etc., that require the ship to be anchored, moored or maintaining station when underway. The design should thus emphasize those characteristics and capabilities that enhance and extend the ship's ability to continue stationary and stationkeeping operations in relatively high sea-state, wind and current conditions. The goal should therefore be to design a vessel with high-sea-state motions approaching those of a dock; i.e., very low and gentle, with good stability and stamina, and with a very broad salvage worksuit.

The size and speed of most ships developed over the past 15 years (tankers, roll-on/roll-off ships, LPG carriers, container ships, AO's, AE's, LST's, carriers, LHA's, etc.) have increased dramatically. Also, many of our major defense assets operate on and in the world's oceans. Thus, this new ARS will have to contend with very large and possibly very valuable strand victims with much higher ground reaction forces, and where the consequence of failure due to environmental and political factors may be high. It will have to support a broad range of research and development items and have to contend with situations such as the Thresher and Scorpion losses and the Palomares bomb and F-14/Phoenix missile incidents where very sensitive political and defense considerations will require an immediate and positive resolution. Accordingly, it is imperative that our Navy's salvage forces be given the highly capable and functional salvage, work and rescue platform that the OR calls for (reference 1). Just another ship will not fill the bill. We need something with "CAN DO". We need an ocean-tamer.

DISCUSSION

RECOGNIZING NEW TECHNOLOGY

The existing wide-beam ARS-38-class salvage ship has been an excellent salvage and rescue platform when compared with other contemporary salvage and rescue ships. However, a similar, duplicate or other monohull design as a circa 1980 replacement hull would ignore applicable technology advancements and shackle future U.S. Navy salvors to a hull form which, although excellent for some uses, embodies major features that inherently limit its use as a salvage and work platform. A relatively new but proven hull form, the semisubmersible ship, initially pioneered as an all-weather mobile drilling platform by the oil industry, and more recently in the form of a low-drag, high-speed range platform, the SSP KAIMALINO, by the Naval Ocean Systems Center would, in a "Fat Albert" high-displacement lower hull configuration, ideally fit the requirements of this new salvage ship. This hull form will greatly increase the high-sea-state and general operational capabilities of our salvage forces and increase them by a factor of at least three over virtually any displacement monohull or multihull catamaran design.

The expense and lead time requirements for Naval ship procurements make it mandatory that designers and operational commands that establish and approve operational requirements keep abreast of all significant technology advances to ensure that the capital outlay is not expended on an obsolete, low productivity design. This is especially true now, considering our current Naval competition problems and the limited ship construction budget available.

Using the wrong hull form would be the gravest mistake possible for a specific ship requirement; it is so fundamental and irreversible. The design recommended by reference 2 makes this error. If this design prevails, our Navy and salvage forces will be tied to a new but obsolete fleet of salvage ships whose major asset will be clean and comfortable dockside accommodations. They will never be able to perform the complicated deep water emplantment, recovery, ocean engineering and salvage tasks our future Navy will most certainly face. Their structure will simply not allow them to carry the new generation salvage equipment, and if they could they would never be able to use it effectively due to their uncontrollable, rogue-like motion behavior. See appendix C for an extremely interesting account of the F-14/Phoenix missile recovery off Scotland. It has been copied and included as received since, although not its purpose, it very clearly and succinctly highlights the severe limitations of a monohull for salvage and recovery operations. The oceans present a very rough and hostile environment, one that can change from serene calm and placid conditions to a howling maelstrom in a matter of minutes. We now have the know-how to build ships and platforms that can contend with and effectively operate in these very rough ocean conditions. It should be used.

WHY NOT SWATH?

The semisubmersible type ship – SWATH, as it is now called, standing for Small Waterplane Area Twin Hull – has all the attributes necessary to satisfy the requirements of this OR. This statement is not based on estimates, guess work or supposition. It is based on

the well-demonstrated operational capabilities experienced and proven by the SSP KAIMALINO in its support operations to the CAPTOR program off Kauai (reference 3), and on the thousands of successful at-sea well drilling and completion operations conducted by an innovative petroleum industry using semisubmersible and jack-up rigs all over the world. The Navy must recognize and utilize this new U.S.-developed technology. The purpose of this paper is to prevent a mistake from being made, primarily by pointing out the tremendous advantages that a semisubmersible, or SWATH-ARS, would provide over the monohull design being proposed. Their gentle motion qualities and favorable structural arrangements seem to fit this OR perfectly.

While reading of the SWATH-ARS advantages that follow, bear in mind that the only ship-related salvage and rescue capability improvement contained in the ARS-46 monohull design is an increase in horsepower with a greater bollard pull. All other improvements more correctly relate to habitability, convenience and subsystem improvements, as distinct from ship or platform capability improvements. The design promises at best a continuation of our present limited sea-state-three salvage and work capability. The SWATH, however, will extend this through sea state five and probably into the six region and also open up new techniques and platform capabilities that are simply not available with either monohull or catamaran type hulls. Make no mistake: the motion qualities of a SWATH are vastly different from those of a catamaran. The SWATH is a very low motion response platform, while the catamaran is a very high motion response platform. This distinction is made early and emphatically to quell the fears of those who worry that we are proposing a Hayes (AGOR) or Pigeon(ASR) type catamaran hull. A catamaran has large, widely-spread waterplane areas, while the SWATH has small, widely-spread waterplane areas. They may look alike in a gross sense, but they are absolute opposites from a motion standpoint. The SWATH will provide excellent stability and low, very gentle motions when in heavy seas, regardless of whether it is traveling at high speed or is hove to, dead in the water. No other hull form can provide this spar-buoy-like gentleness, so comfortable for the men and easy on the equipment and structure. Figures 1 and 2 provide isometric and conceptual drawings of the 3500-ton SWATH-ARS proposed by this paper. The key features to note are:

- The large-displacement lower hulls with multiple lift points.
- The relatively large struts with 600- to 800-ton belly-lift hawse pipes and the large, 15- to 45-foot operational draft range.
- The lock-out/lock-in equipment hatches below the forward struts.
- The long, low sponson decks with anchor billboards and wire troughs.
- The large upper helicopter deck capable of CH-53 operations.
- The covered well and submersible/equipment hangar.
- The universal lift frame for 0- to 60-ton recoveries to 800-foot depths.
- The dual hydraulic 20-ton traveling cranes.

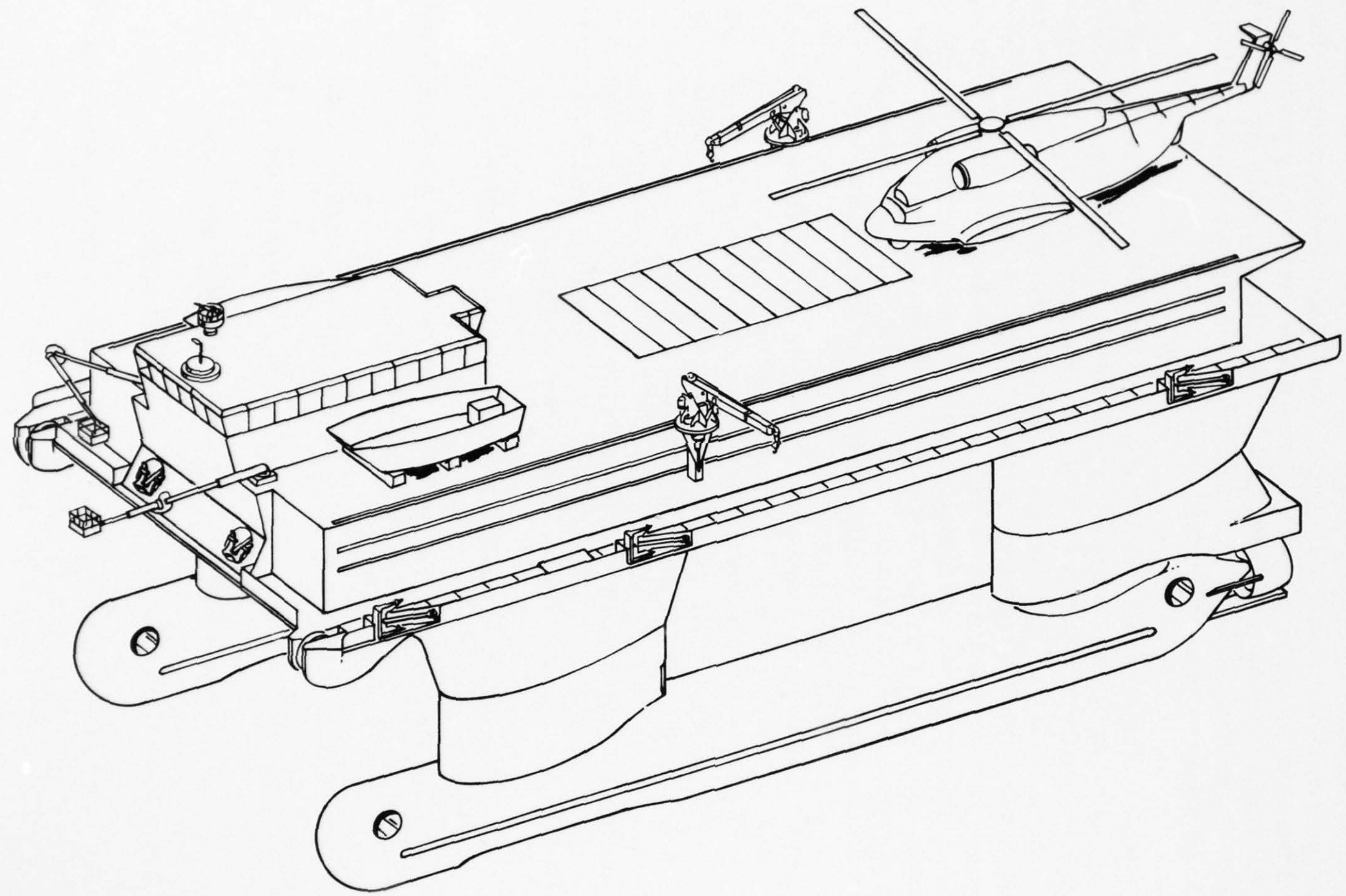

Figure 1. General envelope design of a SWATH-ARS.

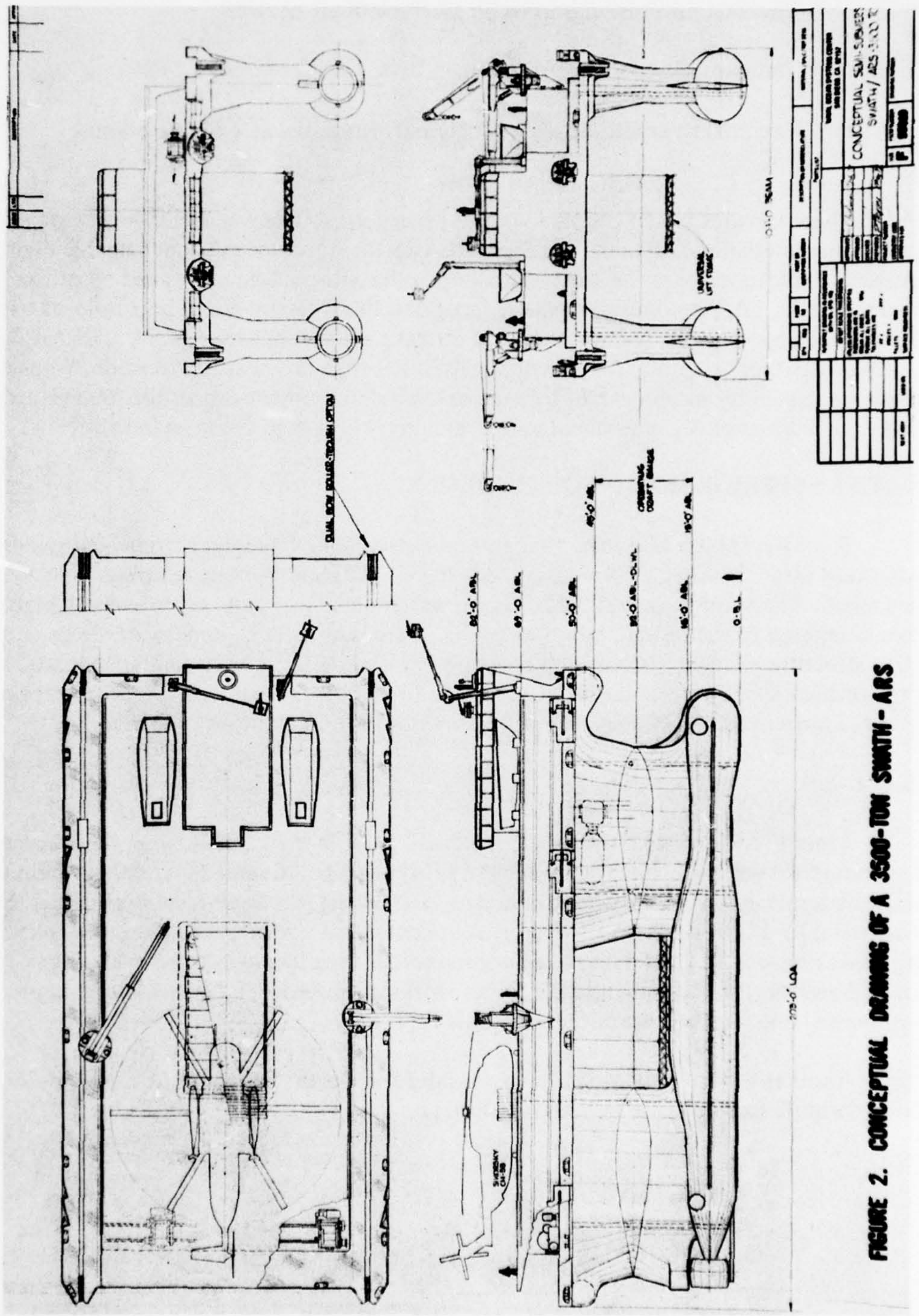

Figure 2. Conceptual drawing of a 3500-ton SWATH-ARS.

- The dual towing winches.
- The dual propulsion units with steerable Kort nozzles.
- The multiple cross-thrusters (4).
- The dual hydraulic articulated man-lift fire assistance rescue booms.

These features, when coupled with its excellent stability and gentle high sea state motion characteristics, will make the SWATH-ARS the most versatile and capable diving, salvage and rescue vessel in the world. It is hoped that our salvage forces and all others concerned will, after reading this paper, recognize the tremendous opportunity at hand. The cost-effectiveness and greatly increased operational capabilities of a SWATH-ARS seem so very evident, one wonders how its application has thus far escaped attention. When a very significant capability improvement to a major capital investment is possible, that improvement should be carefully considered and, if at all possible, made. Why stand still?

SWATH'S SUPERIOR MOTION QUALITIES

The SWATH is a hull form that embodies two relatively large, submerged underwater hulls attached to an above-water, box-shaped platform by four relatively thin, streamlined struts. The main features of this design, which make it a very superior work platform when compared to the normal monohull designs, are that its large underwater hulls and house structure provide high-motion-resisting mass while its four streamlined struts, by virtue of their small waterplane areas, greatly reduce the wave-induced forces attempting to move the large mass. An explanation of its superior motion qualities follows:

HEAVE

From F = Ma, when the Force (F) is small and the mass (M) is large, the resulting acceleration (a) will be small. Thus, for SWATH-type ships, the small waterplane areas of the struts result in low acceleration forces working on the relatively high mass of the ship. These small forces working over the short finite period of a wave passage result in very low amplitude motions. An equal displacement monohull with its much larger waterplane area would, however, produce much larger forces working on the same mass resulting in proportionately much greater amplitude motions.

Another way to look at this is to consider it from the standpoint of the dipping period formula for the heave period of a ship; i.e.:

$$Td = \frac{2\pi}{\sqrt{\dfrac{12gTPI}{\Delta}}}$$

where Td = the natural dipping period in seconds

g = the acceleration of gravity

TPI = tons-per-inch-immersion = $\frac{A}{420}$

A = waterplane area

Δ = displacement in long tons

From this formula it can be seen that as the ratio of tons-per-inch-immersion to displacement gets small, as it does in the case of a SWATH hull form, the heave period increases which in effect means that the SWATH has a very low heave response. Actually, the true heave period would be greater, especially for the SWATH hull due to the high drag of the underwater hulls when subjected to vertical motions – the dipping period formula above does not allow for drag factors. The importance of this low response and the much longer natural heave period is that any heave that does result would be applied slowly at very low accelerations so that chafing and snap loading in over-the-side lift lines, hoses and tethers, and also in anchor, mooring and towline systems, would not be the problem with a SWATH hull that they are with a monohull. The Naval Ocean Systems Center is planning a program to develop an acceleration-sensing black box to help Naval personnel properly size over-the-side lift and tether lines to eliminate the line breakage problems and subsequent hazards that often occur due to the relatively high vertical acceleration forces encountered on board Naval monohull and catamaran type ships today. The justification statement prepared to establish funding for this project is given in appendix B. Additionally, the Supervisor of Salvage is funding a project being handled by Dr. Liu of CEL to investigate the use of ram tensioners to help mitigate and reduce snap loads in over-the-side lift lines. Why not utilize a hull form that will virtually eliminate the basic motion roots to these problems?

The natural heave period for a salvage or work platform should be designed to be long with respect to the normal range of wave periods expected so that the hull itself acts as a filter making the ship insensitive to wave-induced heave forces. This, of course, is an easily obtainable goal for a SWATH since it is in fact one of the natural consequences of its hull geometry. This would, however, be virtually impossible to achieve with a monohull without requiring it to operate at a very exaggerated deep draft or with ridiculously excessive tumblehome. The major feature of the monohull alluded to above which severely limits its capabilities as a useful salvage platform is, of course, its large waterplane area.

ROLL AND PITCH

In addition to its much lower heave response, the SWATH hull form also offers relatively much gentler, i.e., longer roll and pitch, periods than the monohull form does. In the case of roll, this is due to the very wide beam and spread of the lower hulls. This results in a large transverse mass moment of inertia – much greater than occurs in an equal displacement monohull – this represents rotational inertia and resistance to rotation or

roll motions. Additionally, the roll-inducing torques would be much smaller due to the very nominal waterplane area moment forces acting on the small strut areas about the longitudinal or roll axis so that, although the SWATH has excellent transverse stability characteristics, its high rotational stiffness and relatively low wave-induced righting torques result in very long and gentle roll periods. A SWATH will filter out or greatly limit the effects of most wave-induced roll forcing functions so that those roll motions that do occur would do so very slowly and result in very low roll angles. Similarly, the pitch period is also longer and more gentle for a SWATH. However, in this case it is due to the much smaller waterplane area moment of the SWATH about its transverse axis so that even though the SWATH's Longitudinal Mass Moment of Inertia is also lower (has less rotational inertia than the monohull due to its lower length to beam ratio, i.e., 2 to 1 versus 5 to 1 for the monohull), its longitudinal waterplane area forcing torques would be so very much lower that it would still produce a relatively much longer pitch period. Accordingly, and as in the case of roll, the SWATH would filter out and greatly limit the effects of most wave-induced pitch forcing functions so that those pitch motions that do occur would do so more slowly and result in relatively low pitch angles.

The actual pitch and roll periods would, of course, depend in each case upon the relative location of the vertical center of gravity and the related metacenter as is shown by the ship rotation period formula shown for both roll and pitch periods below:

$$T_R = \frac{Ck_T}{\sqrt{GM_T}} \text{ and } T_P = \frac{Ck_L}{\sqrt{GM_L}}$$

where T_R = the roll period in seconds

T_P = the pitch period in seconds

C = a constant

k_T = transverse mass radius of gyration

k_L = longitudinal mass radius of gyration

GM_T = transverse metacentric height

GM_L = longitudinal metacentric height

Again, these periods would actually be larger for the SWATH hull since the above formulas do not include the effects of drag. This assumes that the immersed lower hulls and struts of a SWATH would present larger drag and damping effects for pitch and roll rotations than would occur from the underwater form of a monohull.

HEAVE, PITCH, AND ROLL PERIOD ADJUSTMENT

A SWATH's struts have the potential of including vented or floodable sections so that the effective waterplane areas may be reduced even further to allow increasing the heave, roll and pitch periods. This, in effect, would introduce a "free communication" effect, thereby making it less sensitive to wave actions to further reduce its heave, roll and pitch motions. The area of the floodable sections would, of course, have to be limited to ensure that a positive transverse GM remains. The key to controlling this would lie in monitoring the roll period; i.e., if it were already above some limiting value, then the ventable sections would not be flooded. An error would not be critical since the SWATH would simply assume a slight list, immediately correctable by adding low ballast to drop the center of gravity, or by closing the strut vents to raise the metacenter. Relatively small, incrementally floodable sections would provide a detuning capability to ensure very limited and gentle motions over a broad spectrum of swell periods. The floodable sections need only include those areas or volumes immediately at and above the operating waterline. This feature could prove very desirable for a SWATH configured ARS.

LOAD MOMENT AND UNDERWAY MOTION CONSIDERATIONS

Heel and trim moments introduced by over-the-side lift lines, crane loads, beach gear pulling forces, etc. would be counteracted by an automated ballast transfer and motion control system. Alternatively, the SWATH could elect to sit on the bottom, a capability discussed further on, to eliminate these problems in shallow water where good or favorable bottom operating conditions exist. Underway trim control for Munk (pitch) instability would be provided by trim canards if needed, again actuated by an automatic control system. The automatic control systems cited here would be standard state-of-the-art control systems requiring no new or innovative development effort.

RESERVE BUOYANCY

The large watertight and subdivided house structure above the struts on a SWATH represents a tremendous above-water reserve buoyancy feature making the SWATH an inherently very safe hull form. Damage assessment studies on the SSP KAIMALINO have shown that the SWATH hull form, with proper topside watertight subdivisions, can survive severe damage from any direction.

STRUCTURAL AND GEOMETRY RELATED FEATURES

Although motion qualities form the basis for the SWATH-ARS recommendation, they are by no means the only arguments for its use. Other very useful structural and geometry-related features and capabilities become available that guarantee a highly functional, multipurpose vessel with assets that are not available from virtually any displacement monohull or multihull catamaran. Some of the more valuable of these features and capabilities follow.

PROPULSION

The widely spread hulls of a SWATH-ARS allow for a very advantageous dual propulsion system. Each should be powered by a state-of-the-art dc diesel electric propulsion system which uses multiple diesel generator sets, large-diameter, controllable-pitch propellers and steerable Kort nozzles. The system should be sized to provide a speed of about 14 knots with a bollard pull of at least 60,000 pounds, and preferably 80,000 to 90,000 pounds from each lower hull. The bollard pull should be high to allow large wrenching forces to be applied to strand victims by alternating power levels on the two widely-spread shafts. Dual towing wires and winches would aid in the establishment of these wrenching operations. It should be pointed out that a 14-knot capability by a SWATH-ARS would really be equivalent to some higher speed level for a monohull or catamaran since the SWATH-ARS could much better maintain its speed in rough and high-sea-state conditions; i.e., it is a much more efficient rough weather hull form allowing it to better maintain its transit speeds.

TOWING WINCHES

To take advantage of the widely spread lower hulls and to enhance its ability to assist large stranded ships (a very likely problem), two towing winches should be installed on the lower sponson deck aft. Each should be fitted with 2000 feet of 2½-inch towing wire and mounted on an athwartship rail system with outboard and center load transfer locks, so that either could occupy a centerline position for normal towing operations. These dual tow wires would allow the SWATH-ARS to transfer maximum propulsion and/or beach gear pulling forces to a strand victim and also allow it to introduce wrenching or twist loads to help break and reduce the strand victim's ground reaction forces. The low motion response of the SWATH-ARS and deep operating depth of its propellers will make it an excellent towing vessel, especially in rough sea state conditions.

BELLY LIFT HAWSE PIPES

Heavy belly-lift hawse pipes should lead down from the lower sponson deck through the leading and trailing edges of each strut and pass down through the lower hulls to allow heavy belly lifts to be made by deballasting techniques. Lifts of 600 to 800 tons should be attainable with this system depending on the fuel carried and the capacity of the ballast tanks available (see figure 3).

HELICOPTER PAD

A very stable and clear helicopter pad will be available on the main deck aft. A helicopter with about a six-ton lift would be a very valuable asset to a salvage ship for transferring personnel, anchors, lines, pumps, welders, winches, generators, taking photographs, etc., and in providing rapid survey data.

CENTERWELL

A centerwell with hydraulically-folding main and bottom deck covers to deploy and recover equipment, support submersibles, etc. would prove especially valuable to an ARS.

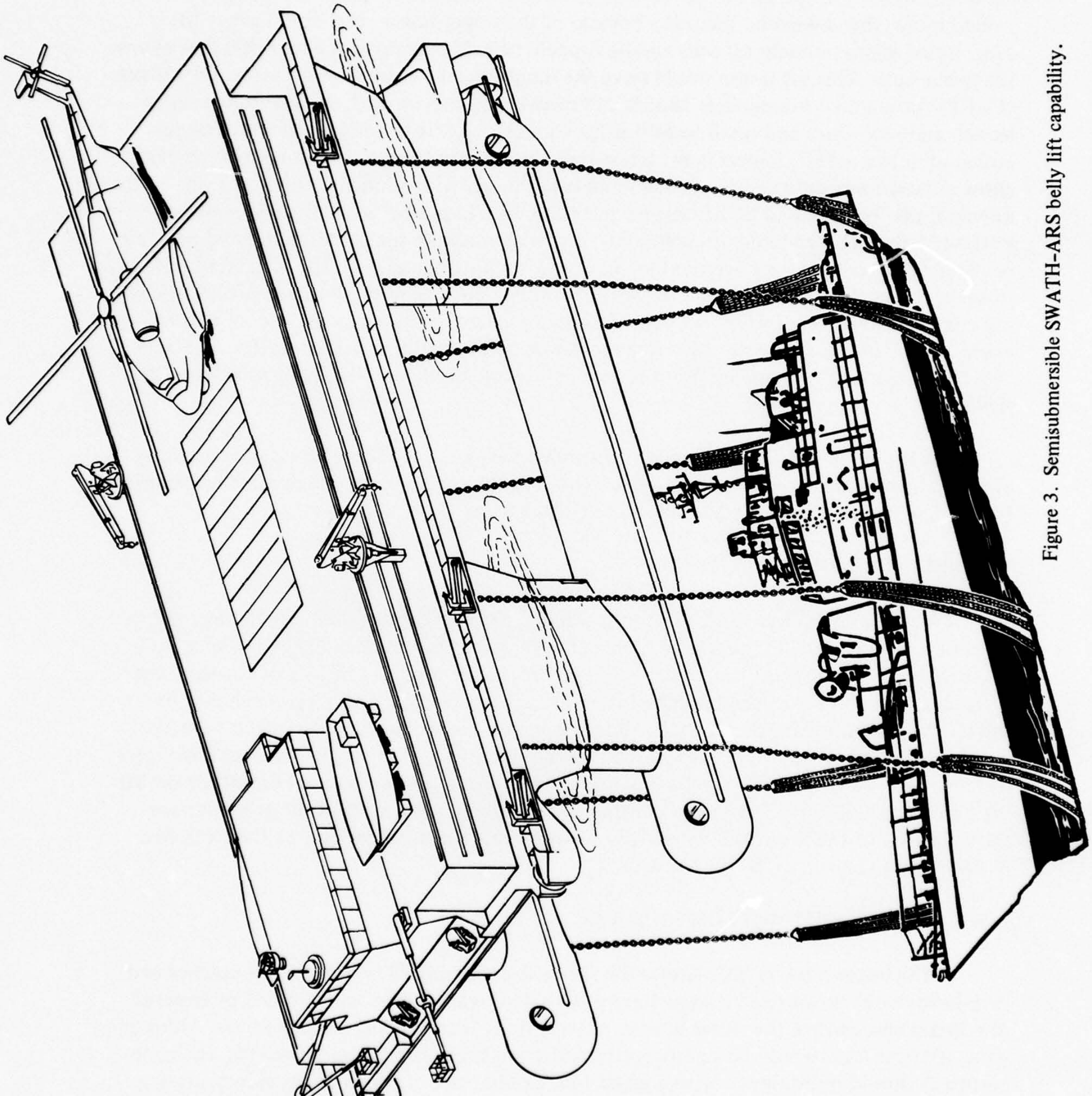

Figure 3. Semisubmersible SWATH–ARS belly lift capability.

UNIVERSAL LIFT FRAME

A universal lift frame with removable expanded metal deck sections should be included. This lift frame should be suspended through and from the centerwell and controlled by overhead winches from the bottom of the upper house. It should have a lift capacity of approximately 60 tons and be capable of being lowered to about 800 feet below the lower hulls. This lift frame would serve the functions of a Launch and Recovery Platform (LARP) for manned submersible launch and recoveries, unmanned free swimming vehicle launch and recoveries and small to 60-ton bottom lifts, etc. It would be capable of being pulled up into a vehicle hanger compartment in the centerwell by the overhead lift system to allow onboard servicing of submersibles and other in-water equipment. The lower side of the universal lift frame would be fitted with pads and eyes to permit attaching and slinging bottomed aircraft, helicopters, small boats, etc. with multiple slings, purchases and nets, etc. to allow their recovery and eventual loading onto support barges, into the hanger, or release in deep waters. The support winches for the universal lift frame should have sufficient cable capacity to allow deeper support operations as diver depth improvements occur. This frame could also be used to provide a low freeboard work platform in sheltered waters. It would also prove valuable for launching and retrieving Boston Whalers, inflatables, rafts, etc. (see figure 4).

A lift frame such as this could be installed between the hulls of a catamaran; however, the high heave accelerations of a catamaran would introduce very high mass acceleration forces, making it a very risky and dangerous installation.

TRAVELING HYDRAULIC CRANES

Two traveling, hydraulic, 20-ton rotating cranes that travel the full length of the ship would be carried, one along each side, on a set of top and lower side rails with a very positive carriage lock system. Each crane would be capable of servicing its side of the ship, over the centerwell and across the middle of the bow and stern areas. Crane power should be provided by an onboard diesel hydraulic power unit. Both cranes would store with the booms low and horizontal, pointing aft along the side of the ship to allow a clear helicopter pad area aft. A two-part lift purchase on each crane should incorporate a Ferranti or similar type constant-tension load transfer control system to eliminate snap loadings when transferring items to and from the workboats or other craft and barges due to their relative motions with respect to the SWATH-ARS.

LOCK-IN/LOCK-OUT BOTTOM HATCHES

The bottom lower hulls under the forward struts should be fitted with hatches and lock-in/lock-out pressurized compartments with deployable skirts which could be lowered to contain and control the water interface oscillations from passing surface waves. Although wave action effects would be significantly reduced at these compartment depths, each compartment should be equipped with a glassed-in, closed control booth to provide operating personnel protection from pressure oscillations should they become annoying. One of these lock-out compartments should be used to house and deploy a PTC to support both air and mixed gas diving systems, and the other to house and deploy a suitcase-sized new generation Remote Unmanned Work System (RUWS). Retractable PTC and vehicle guide systems would

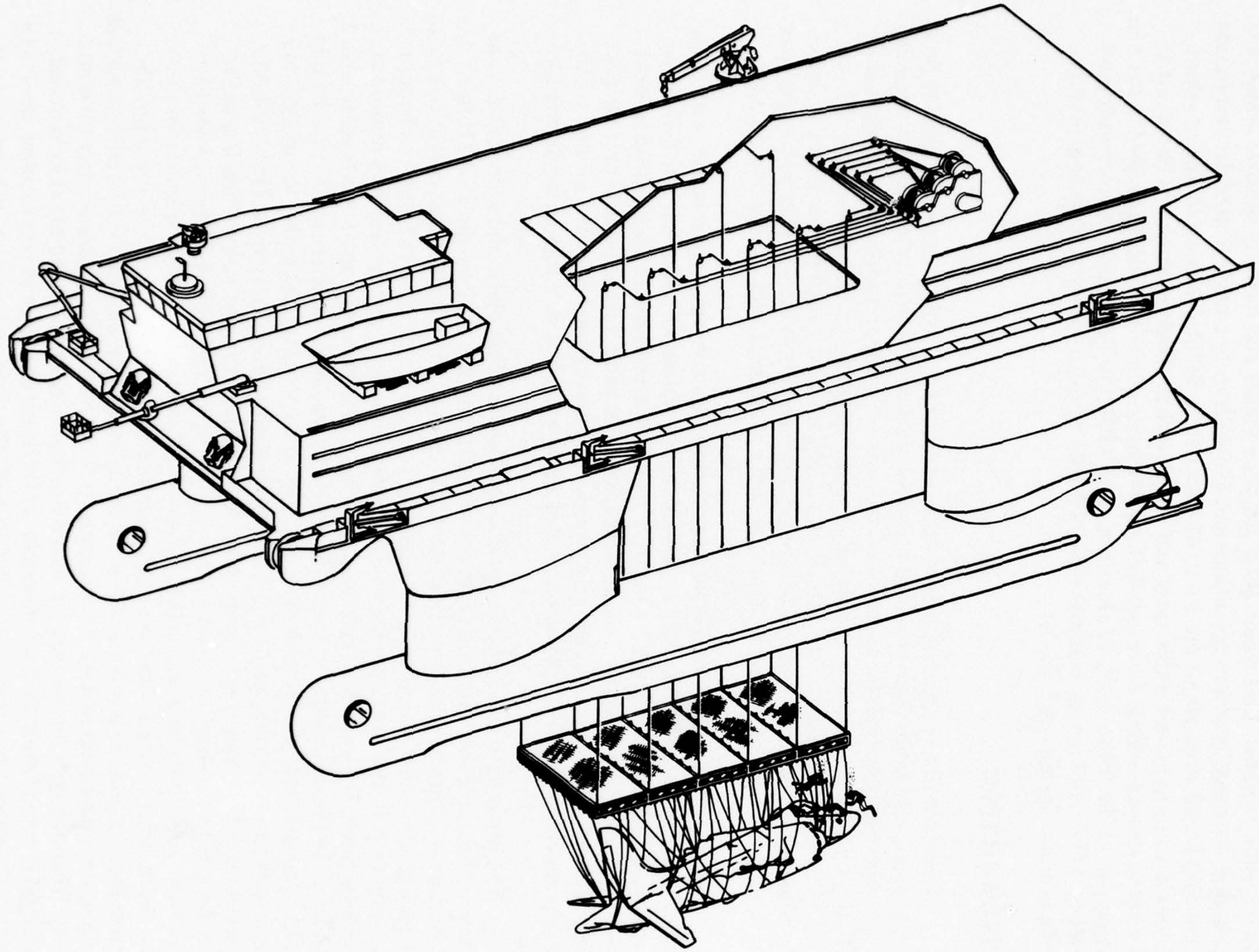

Figure 4. Universal lift frame for 0- to 60-ton recoveries to 800-foot depths.

be incorporated to protect and guide the respective systems through and below the hull while internal rails and guides would ensure that the PTC assumes the proper alignment to facilitate hatch mating and personnel transfer through a transfer lock or directly into a recompression chamber. This would allow the deployment and recovery of such operations, eliminating the rough interface conditions and allow divers to complete their decompression aboard ship for all stops above the 35- to 40-foot depth. Scuba divers could also use these lock-out hatches to permit water entry and return without having to enter or climb out at the surface. One additional diver lock-in/lock-out compartment should be located at the rear bottom end of the forward strut (which houses the PTC) to be close to the recompression chamber. This would permit below-the-surface diver egress/ingress when the ship is sitting on the bottom (see figures 5 and 6).

BOTTOM-SITTING

A bottom-sitting capability, as is sometimes used by offshore semi-submersible drilling rigs, could very easily be constructed into a SWATH-ARS to greatly improve its stranding assistance and on-shore salvage capabilities. It is critically important to complete stranding assistance operations as rapidly as possible so as to limit the complications of further surf action. This must be done in consonance with adequate surveys and proper planning, however, when ready, the ability of the salvage ship to carry out its salvage plan within the span of a few tide cycles is important. Wave and surf action invariably complicate the task.

Bottom-sitting is an understandably controversial concept since it carries with it the onus of going aground – something seamen naturally equate with disaster. The difference, of course, is that bottom-sitting is a planned evolution carried out in a controlled manner – bottom contact being made by a slow, vertical setdown procedure with little or no impact. Going aground, however, is sudden, unplanned, and comes from horizontal motion where the ship impacts and drives hard aground in shallow water – a very significant difference.

The lower hulls should be designed with heavy bottom plates and a floodable, compartmented, double bottom system with a watertight tank top to allow the SWATH to sit on the bottom for those shallow-water operations where the bottom and other conditions make this advisable. When this is done, sufficient water ballast would have to be taken aboard to ensure that the bottom reaction forces remain high enough to prevent any hull motion at the higher tides. The small waterplane areas of the struts make this operation feasible with a SWATH since the wave-induced forces on the struts would be relatively small; i.e., the ship would never get lively as a monohull would. Sets of fore and aft hydraulic bottom-locking rams would prove valuable to increase the hull-to-bottom holding friction. This capability would allow establishing towing wire or hand-over-hand hydraulic puller "beach gear like" pulls directly to the stranded vessel without having to set and retrieve anchors. A series of rapid twist pulls could be made, helping to wrench the stranded ship back and forth to reduce the bottom reaction loads and help free the ship. The operation of the hydraulic bottom-locking pins, ballast control system, thrusters and propulsion units should be such as to allow successive pulls and ARS bottoming shifts to be made in approximately 60-minute cycles. When the bottom reaction forces were sufficiently reduced and the ship loosened, the SWATH could take a final position and set its beach gear ground legs to allow the longer steady pull required to work the stranded ship off the shoal or beach and into deep water. The idea here is to allow making the rapid shifts and beach gear wire or towing-wire pulls without having to shift anchors so that the entire operation can be completed on a single or over the course of just a few high tides (see figures 7 and 8).

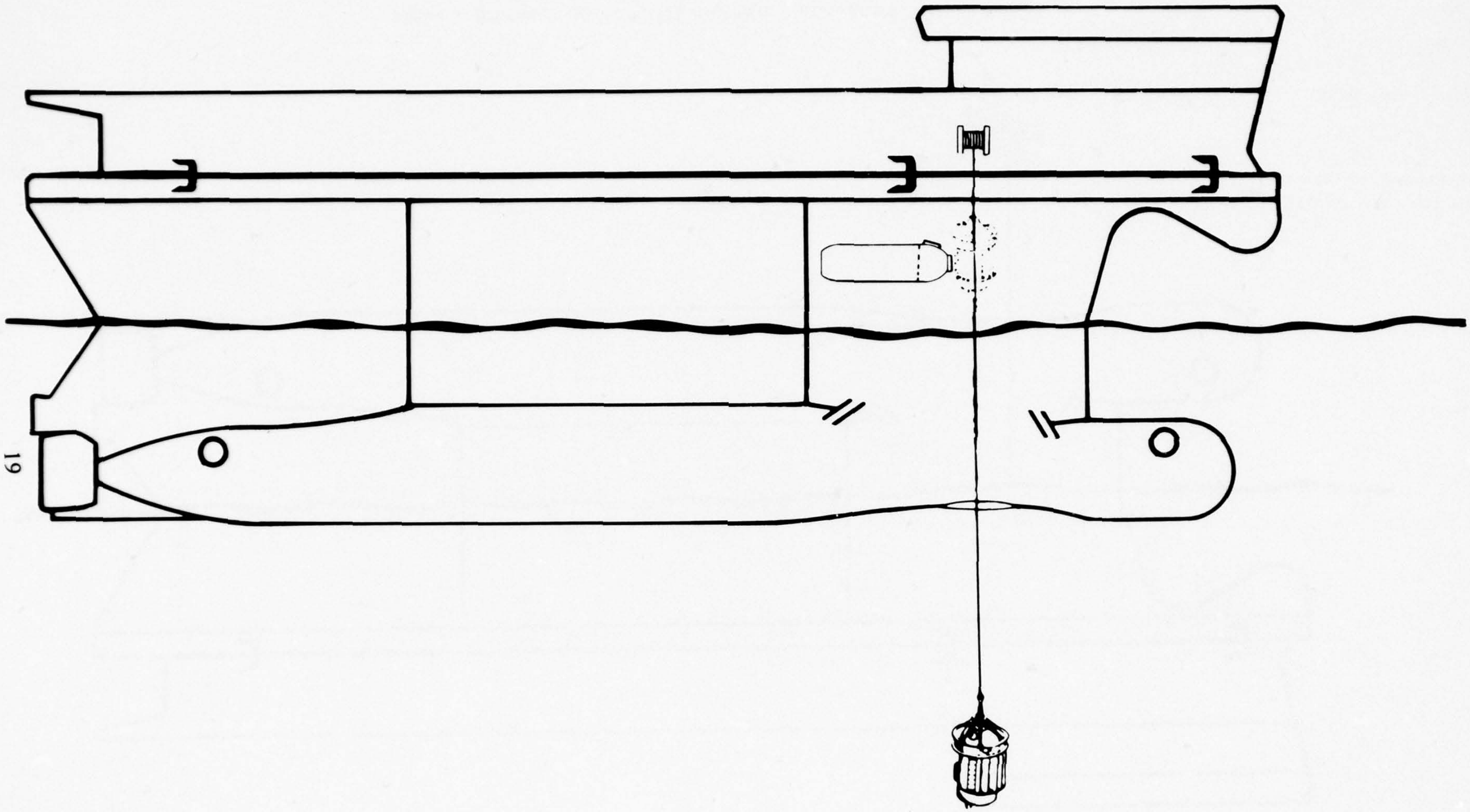

Figure 5. Semisubmersible SWATH-ARS below surface lock-in/lock-out hatches for general and deep PTC diving support.

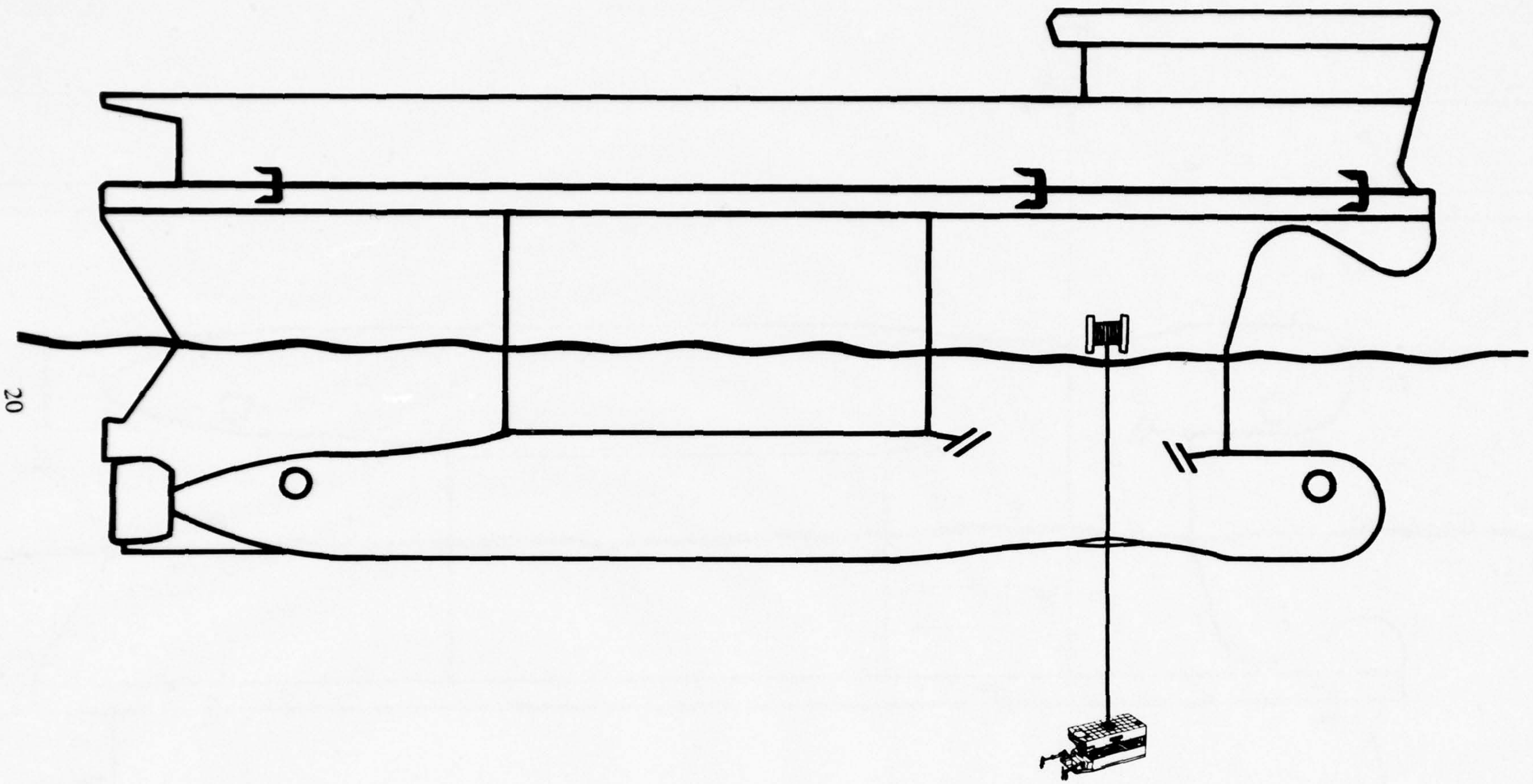

Figure 6. Semisubmersible SWATH-ARS below surface lock-in/lock-out hatches for RUWS, CURV, SNOOPY.

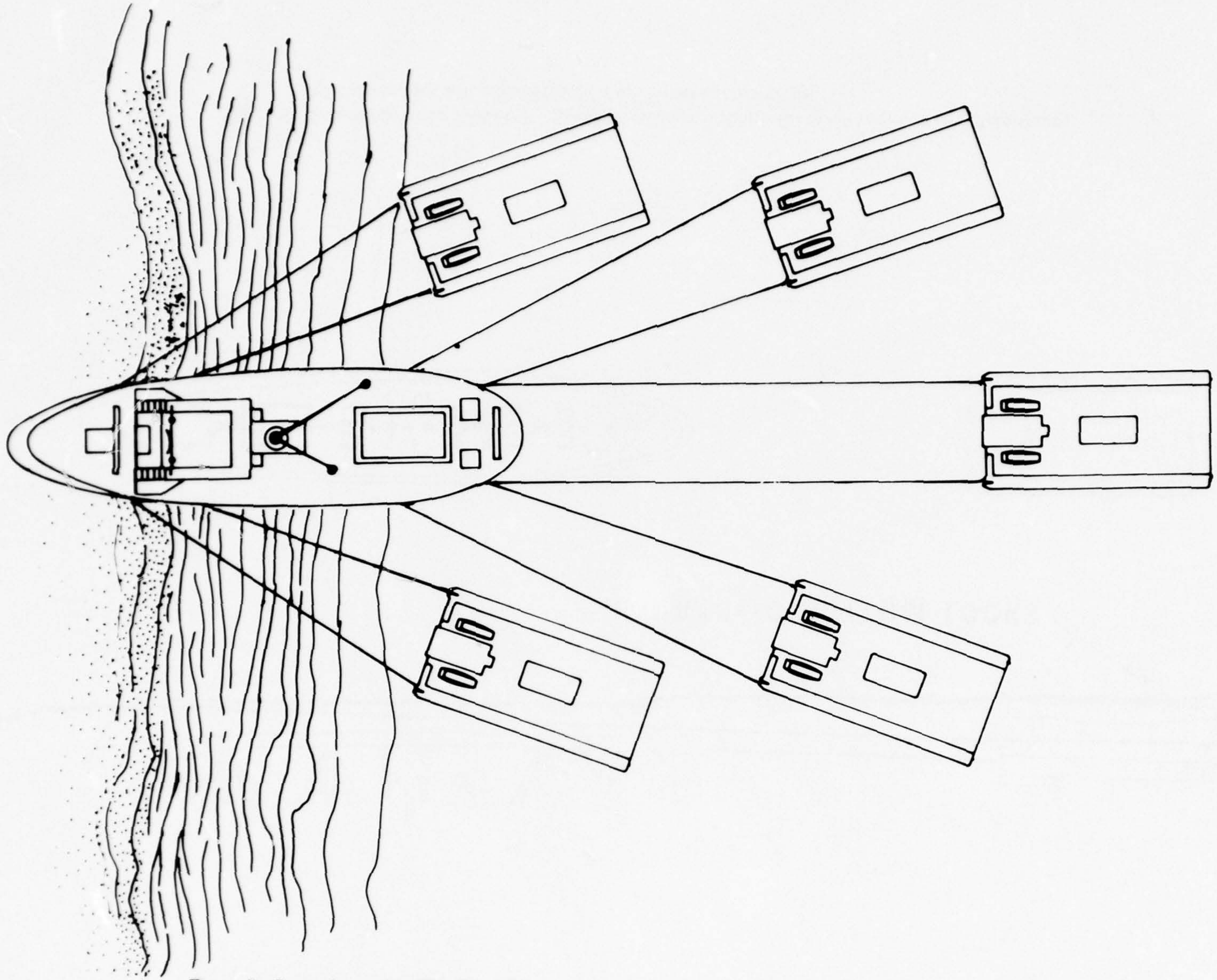

Figure 7. Semisubmersible SWATH-ARS stranding assistance pull position options due to its dual propulsion, improved maneuvering control, large operational draft range (15 to 45 feet) and bottom-sitting capabilities.

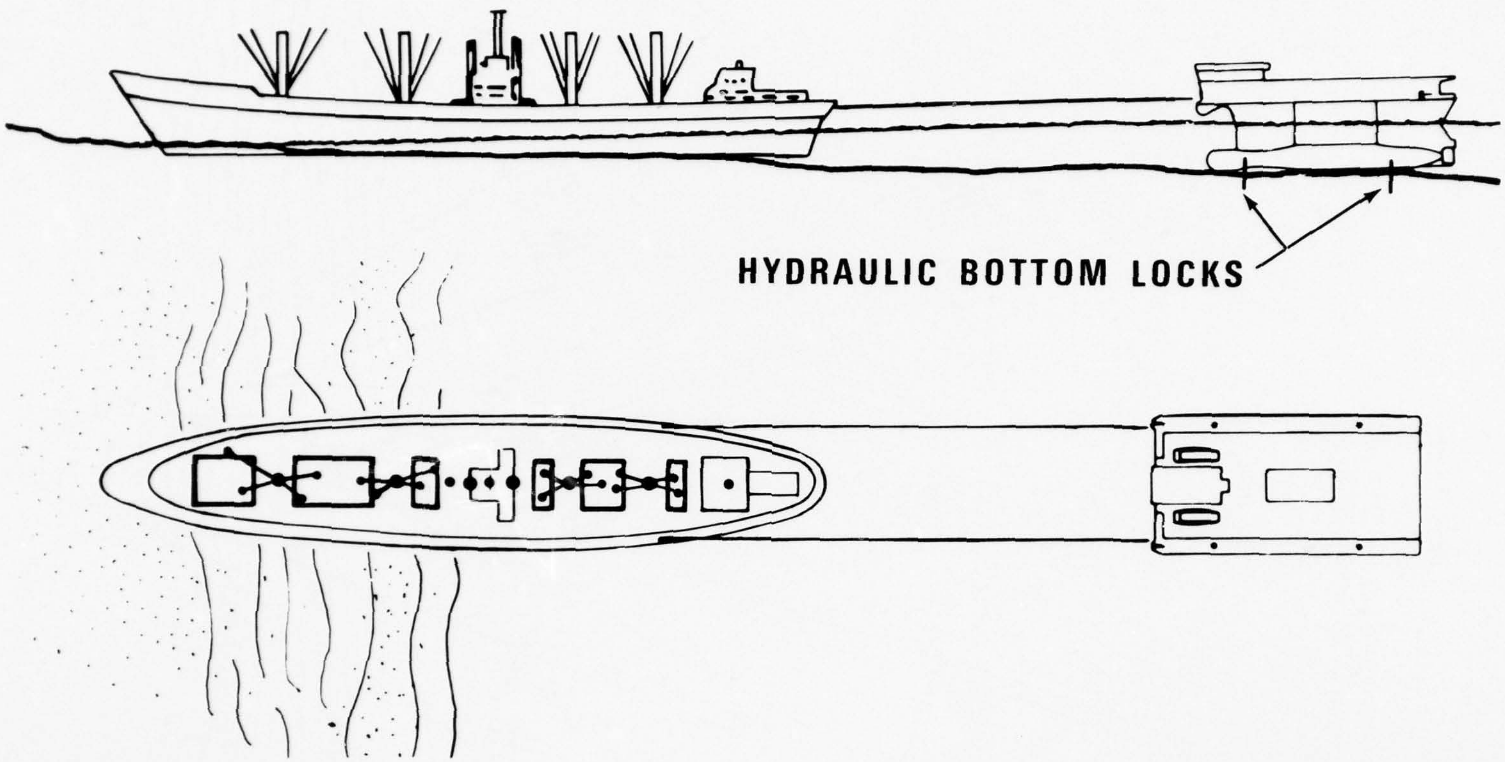

Figure 8. Semisubmersible SWATH-ARS bottom-sitting capability for quick response strand assistance, light grounding, and ground reaction force reduction options.

Sets of eight to ten bottom sounders spaced along the bottom of each lower hull would be needed to provide the bottom slope, contour and obstruction data needed to allow bottom-sitting operations to be planned and carried out safely. Other data, such as the type of bottom, etc., would come from the initial surveys or be provided by divers, bottom reflection interpretations, television or other sampling techniques. A keel manifold wash system would also be required to help spread out high spots during the setdown and to help break bottom suction loads following the bottom-sitting and during the subsequent breakout. The general scenario for setting down in an area with suitable bottom conditions would be to turn on the bottom wash system, ballast down to a touchdown, and then nest the bottoms in by reversing and rotating the thruster and propulsion systems as the additional ballast is taken aboard. Since only 500 to 700 tons of ballast would be required to establish the bottom reaction loads needed, the actual structural loading would be considerably less than those experienced during normal drydockings.

Permanent sets of strain gages should be installed at key points in the lower hull-to-strut-to-upper house load paths to facilitate monitoring of these loads during the bottom-setdown and sitting operations. Just knowing he can sit on the bottom and do it in a controlled and safe manner will greatly aid the salvage master in assisting strand victims by allowing him to confidently take up those positions best suited to provide the most direct and effective pulls and assistance possible. Knowing he has control and can prevent surf, wave and swell action from driving him further ashore will provide a very valuable psychological reassurance in carrying out such operations.

This bottom-standing capability will prove very valuable for battle and post-combat beach and inshore salvage operations. The SWATH-ARS should be designed with relatively high struts to allow the bottomsitting operations to take place in water depths between approximately 15 and 40 feet and still provide a total bottom reaction load of at least 500 tons and an upper hull-to-water surface clearance of about 10 feet when on the bottom at the 40-foot depth. Good functional tools help breed confidence, encourage innovation and lead to expanded capabilities. A highly-functional salvage platform with a bottom sitting capability will result in similar benefits for our salvage forces.

BEACH GEAR OPERATIONS

A SWATH-ARS would make a very convenient, safe and superior beach gear handling vessel. The upper house should be designed with a low sponson deck along each side and across the stern for line-handling, beach-gear, and towing operations. Beach gear would be stored, deployed, and pulls established from the side sponson decks with the 1 5/8-inch beach gear wire led below the deck in a trough with removable deck plate covers and led to recessed hydraulic beach gear pullers to provide maximum protection to personnel. The beach gear wire would lead forward off the ship over a large, eight-foot-diameter sheave grooved to accept up to 2½-inch wire and 2½-inch chain. Three Eels anchors would be stowed on billboards on both the port and starboard sponson decks, with chain and cable sets pre-stowed in portable "ready" launch racks and with crown buoy and buoy cable racks by each anchor. Retrieval buoys and cables would likewise be stowed on deployment racks located to insure a clear and smooth deployment. The two forward anchors and their associated chains, cables and buoy sets would be stowed as necessary to allow for dual

anchor drops. The ship would be heeled for the Eels anchor, buoy and chain deployments to help clear the lower hulls. Washdown hydrants, capstans, cleats, bitts, stopper pads, chain pullers, etc. would be arranged to facilitate an orderly retrieval, washdown, breakdown, inspection, greasing and storage process that essentially preserves and prepares the systems' components for the next deployment. The topside helicopter deck would remain totally clear of beach gear equipment during beach-gear setting and retrieval operations; thus, helicopter support operations would always be available to assist the operation. Additional beach gear sets, hydraulic pullers and power packs should be available to permit deployment of the ground leg by the ship, with transfer of the puller and power pack components to the grounded ship by either a helicopter or workboat so that at least two stranded ship beach gear legs could be set up if required (see figure 9).

The large operational draft range and ballast control system of a SWATH-ARS will allow controlled, high-mechanical-advantage tensioning loads to be established in each beach gear leg (see figure 10). This technique will enable the salvors to always develop the maximum tension attainable for any given bottom-anchor holding condition and will be especially valuable where dual anchor sets are used to help seat and develop the full holding power of both anchors. The SWATH could deballast in either a parallel rise or on one side at a time to effect a maximum straight pull or to effect alternate wrenching pulls. These techniques, used in conjunction with the dual towing winches and dual propulsion systems, will allow a SWATH-ARS to develop very high and alternating loads to help wrench the stranded ship free. They would certainly require that tension readouts be available for each beach gear leg and tow wire to prevent overloading the wires. The key to this capability again resides in the good lift control, i.e., small tons per inch immersion (tpi) that the small waterplane areas of the SWATH's struts provide. The lack of fine lift or heave control with a monohull would, of course, never allow such techniques to be used by a monohull ARS.

SIZE AND DISPLACEMENT

The SWATH-ARS should be sized between 2800 and 3800 tons. It will be possible to develop a very capable and credible design in this displacement range. A well-distributed, dedicated ballast capability near 25 to 30 percent of its design displacement will be required to fully develop and utilize its semi-submersible related draft range, salvage and recovery capabilities. Accordingly, the design must be properly iterated with very careful attention to the structural layout and total weight distribution. Propulsion power, belly lift, crane size, universal lift frame, towing, helicopter size, wave clearance, endurance, and other capabilities cited in this paper all relate to displacement and strut area. Thus, with the tasks and responsibilities they will certainly face and the growth all new systems seem to undergo, the design would best lean toward the higher displacement. However, any SWATH-ARS in this displacement range would produce a very capable, functional and highly cost-effective ship.

ADAPTABILITY

The SWATH-ARS hull form will prove to be a highly-adaptive, versatile and useful vessel. In addition to its basic ARS functions, it will also prove to be a very superior support ship for the purposes listed below.

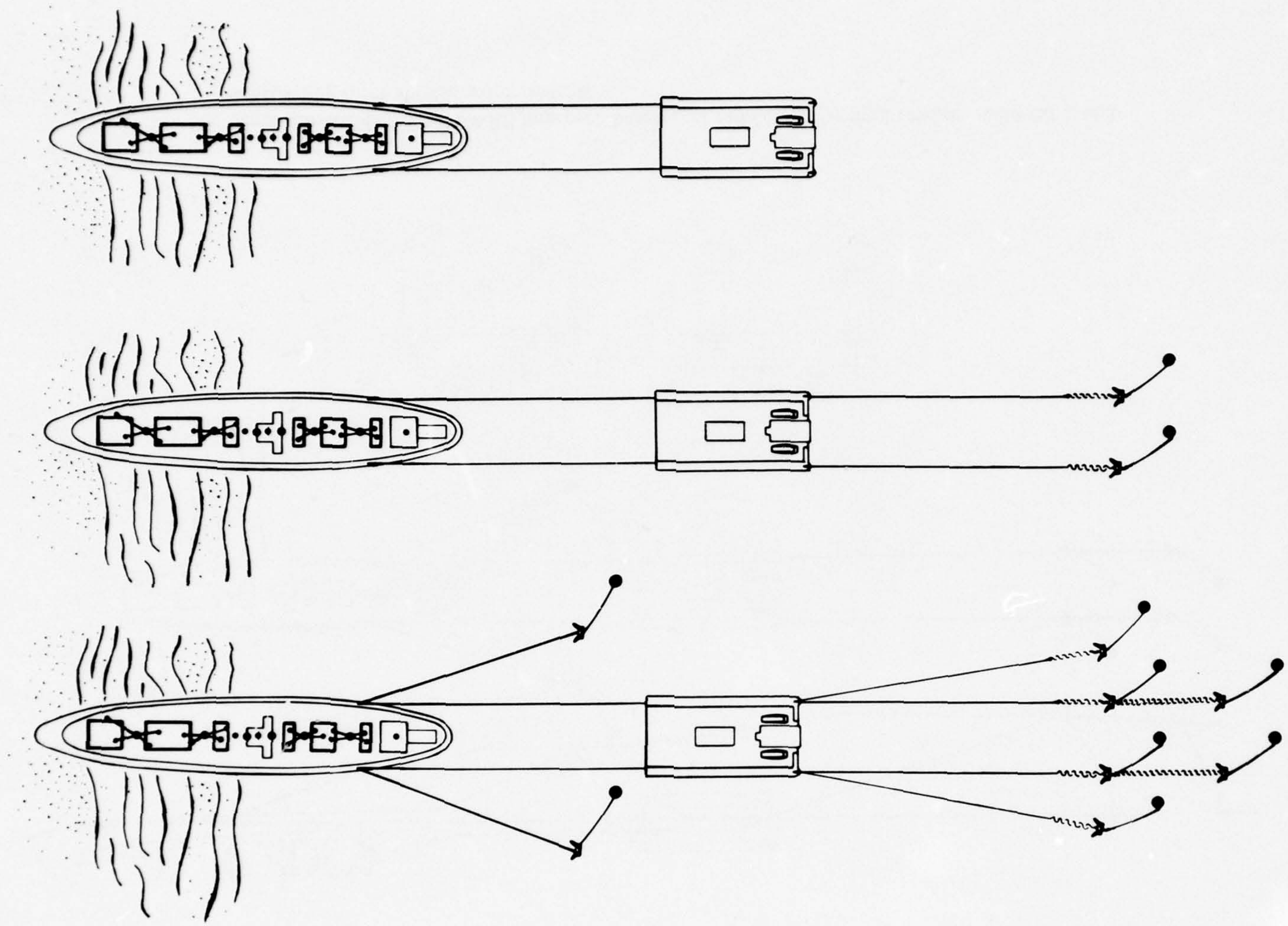

Figure 9. Semisubmersible SWATH-ARS incremental force beach gear options.

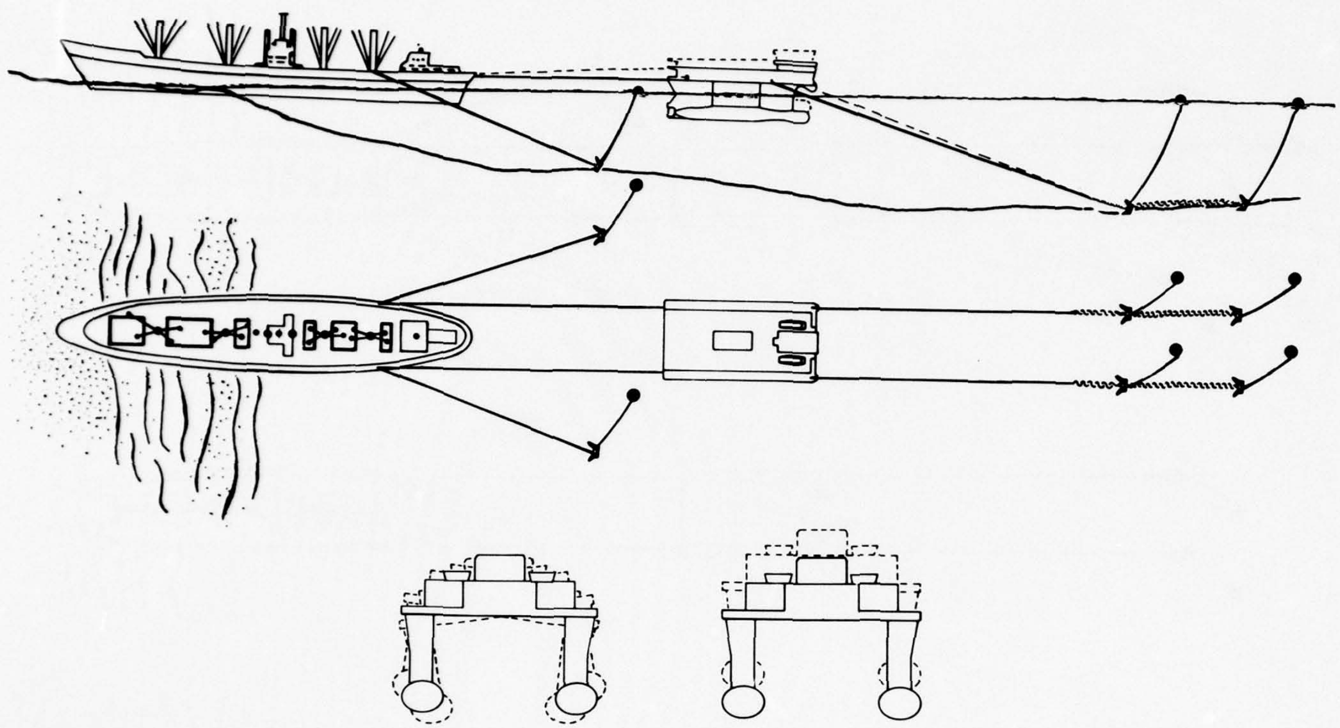

Figure 10. Semisubmersible SWATH-ARS improved beach gear capabilities by dual towline, wrenching, and deballasting force amplification options.

DSRV

Because of its size, large central hanger, universal lift frame and superior high-sea-state transit, stationkeeping and low motion response characteristics, the SWATH-ARS will prove to be the effective and capable DSRV support ship that the catamaran Pigeon was intended to be but could not because of its large, widespread waterplane areas and consequent high-motion response. One of the SWATH-ARS lower hulls could be fitted with a bottom-mating and personnel transfer hatch to allow direct DSRV personnel transfers in reasonable sea state conditions, and could thus effectively operate without a mother sub on the scene. Its universal lift frame could also be used for the DSRV personnel transfers. The partial strut-flooding technique cited earlier could be used by the SWATH-ARS to lower its motion response and help effect the below-surface personnel transfers in the higher sea state conditions. A rescue bell also could be operated through one of the lock-in/lock-out hatches, much the same as the divers' PTC. This would allow a SWATH-ARS to provide very effective submarine rescue support – really a very effective SWATH-ASR (see figures 5 and 11).

TOWED ARRAY

Both vertical and deep horizontal towed arrays and variable depth and side scan sonars could be towed by the SWATH-ARS through one of its lower hull lock-in/lock-out bottom hatches (see figure 12). A low-speed, "quiet" propulsion prime power unit could be located in the upper hull using an acoustic isolation mounting system to allow quiet operations. A portable mast with controllable foils might also be used for a quiet, cheap, low-speed, wind-powered capability.

MODULAR WEAPONS PLATFORM

The forward end of the large upper helicopter deck would provide a very large area for the installation of modularized weapons and other portable modularized systems. Our new generation auxiliaries and service craft could in fact pack quite a sting.

HABITABILITY, EXERCISE AND MORALE

The SWATH will allow at least twice the habitation space for its crew. Additionally, the large helicopter deck cited above will make an ideal basketball, volleyball, tennis and exercise area and will also, with a portable canopy, be the ideal place for all those "successful" post-operation parties their crews will certainly have. These ships will prove to be productivity-, efficiency-, and morale-builders. There is nothing like success to build and maintain the pride and spirit necessary to keep an organization at its peak. Their spacious accommodations and comfortable motion qualities will help maintain that peak.

Appendix A lists the major features that a SWATH ship should have to best fit the requirements of an ARS salvage ship. Figures 1 through 12 are included to help the reader visualize the SWATH-ARS's many capabilities.

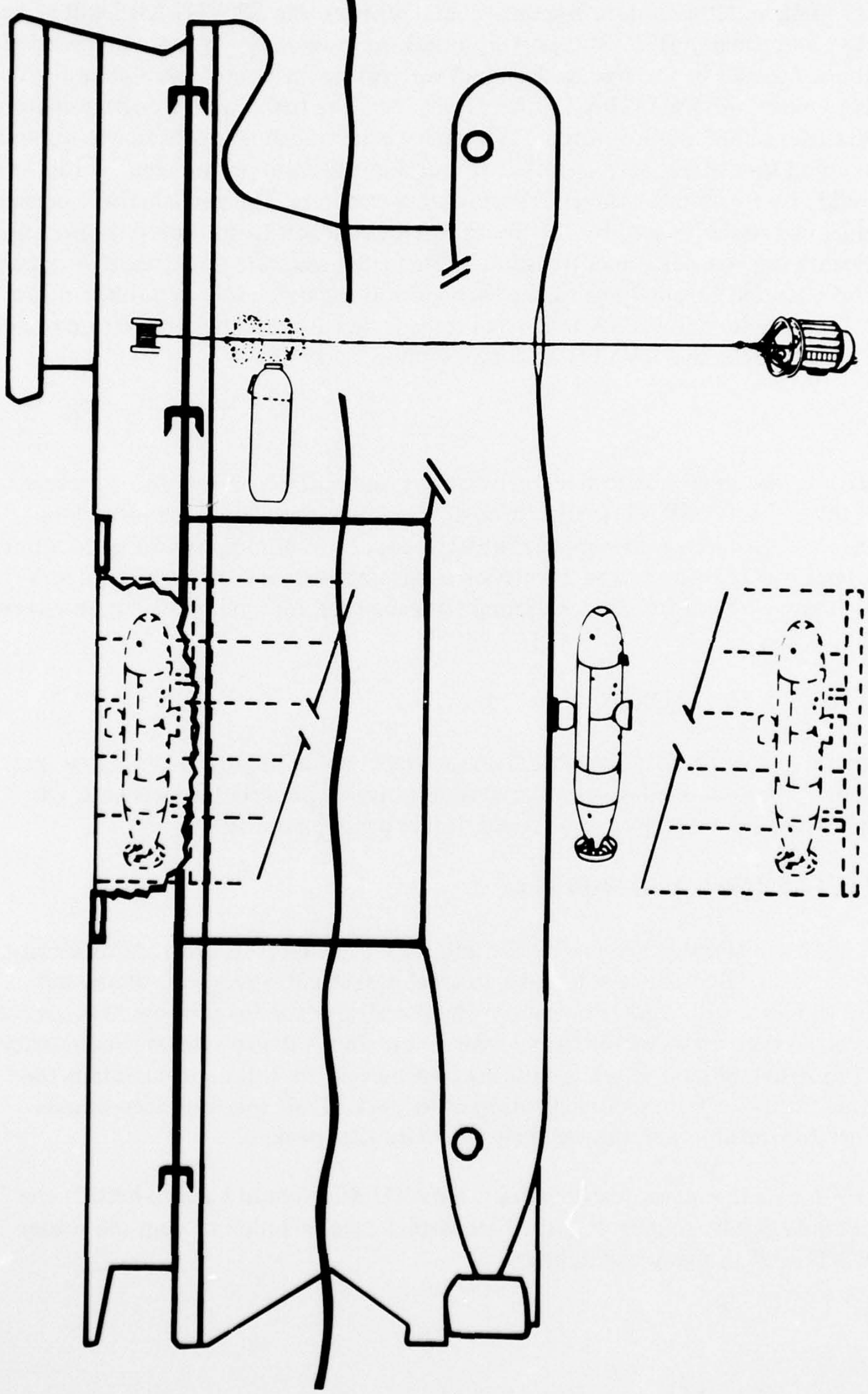

Figure 11. Semisubmersible SWATH-ARS universal lift frame DSRV and SDV support.

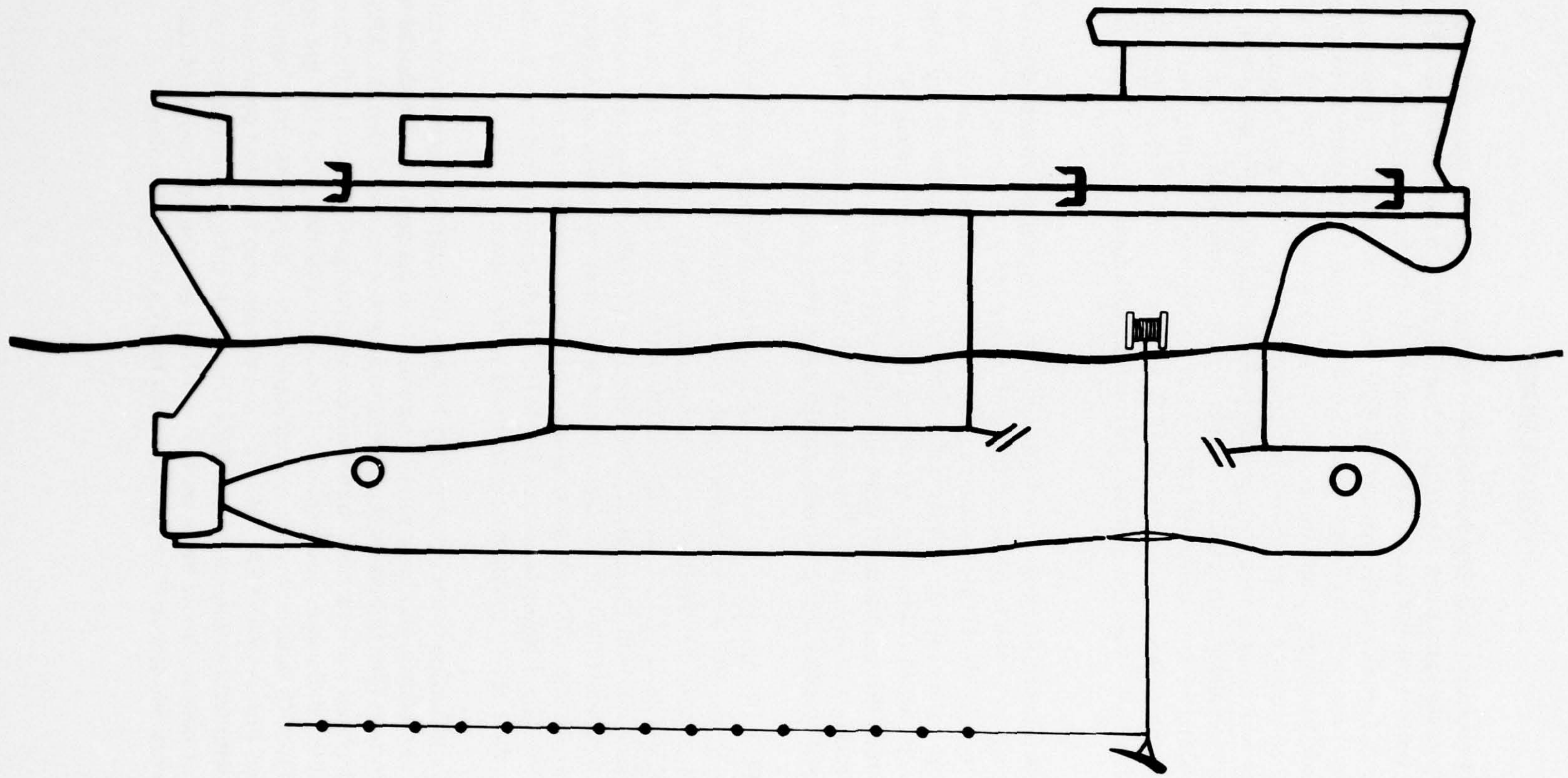

Figure 12. Semisubmersible SWATH-ARS towed array and SDV support.

CONCLUSIONS

The Naval Laboratory and ship development communities have the opportunity to increase our Navy's salvage and work capabilities dramatically. We have in the SWATH hull concept an almost perfect vehicle for the ARS operational requirement at hand. The beauty of this concept for this application is that the SWATH's major assets accrue passively, i.e., strictly from shape. It has no high energy or sophisticated structural or controls requirement to become foil borne, maintain an air cushion or develop some surface effect, etc. to do its thing. It therefore represents a structures related, low risk effort – a lateral expansion of an existing technology which has in fact already been probed. Hull efficiency and propulsion advancements, although always attractive, are not critical to this requirement. Its "Fat Albert" lower hulls and nominal 14-knot speed fall well within the existing semi-submersible-SWATH-diesel propulsion technologies, making the SWATH-ARS an excellent LOW RISK FIRST VEHICLE to establish the basic design and construction techniques for moderate sized SWATHs.

The Navy should proceed boldly with an immediate design effort to provide a SWATH-ARS with a displacement in the range of 2800 to 3800 tons and with as many of the features cited in this paper as possible. If this is done and done well, we will most assuredly slingshot our Navy and salvage forces into an operational capability far beyond that of any other Navy or salvage group in the world. These ships, when their full potential is realized, will act as a strong catalyst to draw this nation, and eventually others, at a highly accelerated pace into rapid ocean engineering advancements. The present high risk in such ventures will reduce dramatically with the stability and sea-kindly gentleness of these ships.

The SWATH hull concept will, with an ARS introduction, very rapidly take over many other Naval Operational Requirements simply because it has so very many superior qualities. The most obvious candidates are: submarine rescue ships, surveillance ships, mine countermeasures ships, small VSTOL aircraft carriers, amphibious container offloading ships (to operate in conjunction with the Logistics Over-the-Shore (LOTS) concept), hospital ships, and particle beam weapons intercept platforms if and when they come to pass. All naval surface ship requirements should undergo an immediate review to assess the potential impact SWATH and SWASH (Small Waterplane Area Single Hull) hull forms would have on their capabilities and on their ability to compete effectively in the future.

A SWATH application is imminent simply because it guarantees improved capabilities. We have the logic, experience, and basic physics arguments to support this. We should use them before contentious foreign powers show us how. It is recommended that the ARS-46 effort be held in abeyance until its basic monohull design undergoes a critical and objective functional, capability, fuel-usage, and cost-effectiveness comparison; *vis-a-vis,* the semi-submersible SWATH-ARS design concept recommended here. Representatives from the Operational Salvages Forces, NAVSEA, PMS 383, and people who have had operational and design experience with semi-submersibles and SWATHs should take part in this evaluation process. The goal, of course, should be to see that our Navy gets the best and most cost-effective salvage, work and rescue vessel possible with today's total technology.

REFERENCES

1. Operational Requirement, Salvage Ship (ARS) OR No. S-1247-SL.

2. The ARS-46 (FY 81) SAIP Presentation by PMS 383 of the Naval Sea Systems Command – Ship Acquisition Project.

3. Hightower, J.D. and R. L. Seiple, Operational Experiences with the SWATH Ship SSP KAIMALINO, Proceedings of AIAA/SNAME Advanced Marine Vehicles Conference, April 1978.

APPENDIX A: SWATH-ARS FEATURES

Major features that a SWATH ship should have to best fit the requirements of an ARS salvage ship are:

1. Large, preferably elliptical-shaped "Fat Albert" lower hulls with the major axis horizontal, to provide:

   - The large displacement and high heave drag desired for the long motion periods required.

   - The large number and distribution of ballast tanks required to allow shallow draft operations, heavy controlled lifts, and to provide good trim and heel control during all lifts.

   - The fuel capacity required for the long range specified.

   - The space required for the propulsion, prime power, auxiliaries, and other machinery equipment.

   - The space required near and under the forward struts to support and control tether-controlled lock-out PTCs, a recompression chamber, suitcase-sized new generation RUWS-type systems, and diving operations.

2. The lower hulls should be shaped as required to ensure that there is no high drag transition zone below its 14-knot design speed. The keel, or baseline, of the lower hulls should, however, be essentially straight, with no protrusions, to allow a bottom-sitting capability. The lock-in/lock-out hatches should be inset and protected by a set of heavy side rails.

3. Tunnel thrusters should be located at the fore and aft ends of both lower hulls with both manual and automatic stationkeeping control modes. The latter should operate in conjunction with the main propulsion units and be capable of using radar, transponder or doppler water mass or bottom references. The thrusters and control system should allow for both two- and four-thruster plus main propulsion stationkeeping operations and be capable of holding the ship on station in up to three-knot cross currents. Good maneuvering and precise stationkeeping control should be provided so that in-water tethered and salvage operations can continue in sea-state-five and hopefully, sea-state-six conditions.

4. The struts should be designed to provide sufficient internal dimensions, soft patches, etc., to allow all major machinery units to be lowered down and through to the lower hulls. It may also prove desirable to provide watertight zones and the controls to allow flooding of up to 30 percent, depending on GM conditions, of the strut cross-sectional areas in floodable zones between three-foot water lines both above and below the DLWL. This would ensure that wave-induced heave motions can be minimized during normal stationkeeping and moored (floating) operations, and prevented for the on-bottom operations cited in the main text.

5. Both lower hulls should be fitted with interrupted heavy rubber or timber/rubber-filled steel rubbing beads on both their inboard and outboard sides. These rubbing beads should have intervening heavy, low profile lift pads spaced conveniently along the full length of the hulls to support in-water diving, recovery and other in-water operations.

6. Two hydraulic man-lift systems with articulated booms and 1000-pound capacity personnel baskets. Each basket should be equipped with a small fire monitor and a hose foam delivery system to provide a firefighting-assistance and boarding-team transfer system. Both deck and basket controls should be provided.

7. Anchors near all four corners of the structure to allow four-point moors and an anchoring capability in up to 600 feet of water.

8. A keel manifold system on both lower hulls to allow water or air to be jetted below to help break bottom suction and also to help nest and spread the load during bottom-sitting operations.

9. Fore and aft sets of bottom hydraulic locks in both lower hulls to increase the bottom friction and reaction loads during bottom-sitting operations.

10. Sets of eight to ten bottom sounders spaced along the bottom of both lower hulls to help provide bottom slope, contour and obstruction data for bottom-sitting operations.

11. Four 35,000-pound capstans fore and aft on the port and starboard sponson deck.

12. Two workboats should be carried to provide workboat support with a backup.

13. Two Boston Whalers and two inflatable Avons or "Z" Birds should be carried.

14. Large-capacity air systems for both ballast control and diving systems.

15. A range of the new Fixed Volume Lift Bags for controlled in-water lifts.

16. Portable airlift and pressure wash scouring systems that can operate from the workboats to help clear bottom areas.

17. Four hydraulic and two normal purchase beach gear pulling systems.

18. Low-light-level TV and lighting systems installable on the universal lift frame.

19. Underwater viewport systems from both lower hulls with internal steel pressure-tight deadlights.

20. A certified helicopter fueling system.

21. Large fuel, freshwater and stores capacities for extended independent operations with an on-board freshwater-making capability.

22. Good low speed control.

23. A concrete pump with a 100-foot articulated arm and flexible hose delivery system configured to operate from one of the small workboats. The delivery system should be capable of being used as a small dredge suction unit. Consideration should be given to incorporating a larger dredge suction stinger and a medium size internal dredge slurry pump to allow a modest dredging capability that could operate with either a modest length discharge line or with hopper barges as locally available.

24. The lower hulls and struts should be designed with scantlings adequate to allow independent operations in ice.

25. An equipment list including pumps, generators, winches, welders, anchors, buoys, wire, stoppers, line, lift straps, shackles, etc. to allow it to carry out its normal ARS functions.

26. Adequate machine, carpentry, electronics and welding shops with reasonable supplies of wood, timbers, steel plate, structural shapes, cement, sand, rebar, etc.

APPENDIX B: JUSTIFICATION STATEMENT FOR BLACKBOX DEVELOPMENT

21 September 1978

ACCELERATION (Load Multiplication Factor) BLACKBOX

There is a need for an instrumented blackbox to provide load multiplication factors when lifting in-water objects from the ships and surface platforms available to the Navy today.

Our experiences at NOSC with the LARP, Anchor and Emergency RUWS Recoveries point to one common shortcoming: a failure to appreciate the importance of the mass acceleration forces which arise when objects are lifted from a heave-sensitive ship. Lift lines are invariably sized from the answer to "what's its in-water weight?", with little allowance made for the acceleration loads due to the mass of the object and the mass of the entrained and imaginary water being moved. In every case from the experiences cited above, the initial lift line parted, creating a hazardous situation, wasting time and effort, and resulting in additional complications for the subsequent larger lift line and/or messenger hookup required.

A blackbox instrumented to sense vertical accelerations at the lift point with instructions on applying load allowances for the mass of the object and the estimated entrained and disturbed waters would be a valuable asset to the fleet service forces.

APPENDIX C: NARRATIVE DESCRIPTION OF F-14 RECOVERY OFF SCOTLAND

On 14 September the USS KENNEDY (CV67) was launching aircraft north of Scotland near the Orkney Islands. At about 2 o'clock in the afternoon several F-14 aircraft were preparing to take part in a simulated defense of the task force. The launch was going smoothly when suddenly one of the F-14 aircraft taxiing to the ship's catapults roared toward full power. The pilot jammed on the brakes but the aircraft began to skid toward the edge of the angle flight deck. At the last possible second, the pilot and the Naval Flight Officer ejected from the aircraft. The ejection seat worked as designed, and the two men, still strapped to their seats, were rocketed 300 feet in the air where their parachutes deployed, and they floated back to the flight deck of the KENNEDY. Fortunately no serious injuries were incurred; however, the F-14 was not as fortunate and sank immediately in 1890 feet of North Atlantic water.

This exercise was being covered by the news media from both European countries and the United States. As luck would have it, an NBC film crew embarked in one of the ship's helicopters was filming the flight deck when the accident occurred. He had a scoop of the first magnitude and soon the accident was being shown on television around the world.

During the excitement on the flight deck the KENNEDY's navigator remained cool and immediately and accurately fixed the ship's position.

As the newsmen reported, two Soviet cruisers and several intelligence ships were in the vicinity and they speculated that they may attempt to raise the aircraft for intelligence if we didn't get to it first. You may recall that shortly before this accident a Russian pilot had flown a MIG-25 to Japan which gave our own intelligence community an unexpected bonanza. Some news reports speculated the Russians would like to get even by getting their hands on one of our F-14 tomcats.

The F-14 is an ultra sophisticated aircraft, and the AWG-9 fire control system has the capability of tracking up to 24 targets simultaneously. It can also launch up to six Phoenix missiles and shoot down targets at distances in excess of 100 miles.

The decision was made to attempt to retrieve the tomcat. The task of locating the aircraft would be difficult, and weather was also a factor as winter approached and the raging North Atlantic would certainly hamper the operation. Even if the aircraft and Phoenix missile were located, the raging seas would make salvage operations difficult, to say the least.

The U. S. Commander Eastern Atlantic was designated as the officer in charge of the recovery effort. The U.S. Navy Supervisor of Salvage was to provide the search team, search and navigation equipment, commercial and non-fleet recovery assets and exercise technical direction of the operation.

The USS SHAKORI (ATF-162) was diverted from Rota, Spain, and designated as the search platform for the operation. SHAKORI was ordered to proceed to Glasgow, Scotland, for outfitting in preparation for the search.

An oil field supply ship, M/V CONSTRUCTOR, was contracted for by SUPSALV to act as the recovery vessel. In addition CURV III, a cable controlled underwater research/recovery vehicle operated by the Naval Undersea Center in San Diego, was flown to Scotland and placed aboard CONSTRUCTOR.

On 20 September SHAKORI arrived in Glasgow and began loading the DECCA Precision navigation system and the side scan sonar equipment. At midnight on 21 September the SHAKORI sailed quietly down the Firth of Clyde and headed out to sea to begin searching for the proverbial needle in a haystack.

Once on station SHAKORI initiated the search by lowering the side scan sonar and began monitoring the sonar impulses that would search the bottom and send a detailed picture to the bridge.

Weather was cloudy with easterly winds of 25 knots and seas 8-10 feet. Higher winds and seas were in store. The first of many problems occurred at 2300 hours of the 24th. The sonar struck bottom during a turn, damaging the cable and the transponder. It took eight hours to make the necessary repairs. By 2300 on the 25th over 4 square miles around the KENNEDY's datum had been covered and no significant contacts were made.

With winds rising at times to 40 knots and waves in excess of 20 feet the SHAKORI was taking rolls of up to 35 degrees. Nevertheless, the search continued. At 0830 a loose antenna connector caused the DECCA navigation gear to spin out of calibration. Since precision navigation was vital to the success of the search, SHAKORI had to leave the search area and proceed closer to the reference system and recalibrate.

SHAKORI returned to datum the evening of the 26th and once again began the search.

The weather continued to deteriorate, and the search continued with no success until 2 October at 1139 when a firm contact was located on a rerun over datum. After making several passes over the contact the weather deteriorated to the point that the sonar had to be recovered. Because of the deteriorating weather, and with fuel and supplies running low, SHAKORI headed for Aberdeen, Scotland on 4 October.

On 5 October SHAKORI arrived in Aberdeen for resupply. A meeting was held to discuss the use of the NR-1, a Navy nuclear powered underwater research and ocean engineering vehicle. In addition another ship M/V OIL HARRIER was hired to augment the recovery team. OIL HARRIER's capabilities included powerful towing winches and a large clear afterdeck. To permit all the ships to have a precision navigation system capability, the DECCA master unit was returned to its shore based location and all units were fitted with hyperbolic receivers. This provided slightly less accuracy than the original arrangement but was adequate to regain the contact position.

Weather again was a problem and sailing was delayed until the evening of 8 October. Heavy seas slowed the transit to the operating area but the search began once again on the evening of 10 October.

Early on the morning of the 14th the contact was relocated. The sonar trace indicated that the contact had been dragged about 300 feet.

On 15 October the weather once again caused the operation to be suspended and all of the recovery forces sailed into Kirkwall, Scotland.

Weather remained poor but on 17 October the ships departed Kirkwall for the salvage site, arriving early on the 18th. SHAKORI commenced sonar verification runs while CONSTRUCTOR and OIL HARRIER just "bounced around" in the heavy seas.

On the morning of the 19th CURV III was launched and started her descent to inspect the contact. Unfortunately, a cable connector flooded out before the vehicle reached the bottom and, when the vehicle was recovered, the NUC technicians found that on-scene repairs were impossible. Once again, all units sailed into Kirkwall, arriving on the 20th.

Because of CURV III's breakdown the decision was made to utilize the NR-1 to verify the contact and attempt to attach a line onto it. SHAKORI returned to the salvage site to meet with NR-1 and her "mother ship", USS SUNBIRD (ASR-15).

The 21st of October was spent relocating the contact. SHAKORI made sonar contact and dropped a deep ocean transponder on top of the contact. Late that evening NR-1 made positive verification that the "needle had been found".

NR-1 reported the tomcat was lying upside down and that a large amount of fish net was tangled around the aircraft which apparently had been dragged from its original position. The fishing trawlers in the area had apparently snagged the F-14 and the mystery of the moving tomcat was solved. Confirmation of the loss of a snagged net was later provided by a large French trawler.

In the meantime repairs had been completed to CURV III and CONSTRUCTOR and OIL HARRIER sailed to once again join the salvage effort.

On closer inspection by NR-1 it was discovered that the Phoenix missile was not on the aircraft.

The SHAKORI passed a choker made of 10-inch-circumference nylon line to the SUNBIRD. The SUNBIRD in turn dropped the choker to NR-1 and the submersible attached the choker to the port landing gear of the tomcat using her mechanical arm. The North Atlantic weather started to howl again precluding any attempt at lifting the aircraft.

After a few days the weather subsided and the end of an eight and one-half inch circumference Nydac line was lowered to the bottom by M/V CONSTRUCTOR. NR-1, again utilizing its mechanical arm, attached the line to the previously placed choker. The surface end of the line was then transferred to OIL HARRIER who took a strain with her powerful winches and began to lift the F-14 from the bottom. When the aircraft was 100 feet from the surface the lift was suspended to allow divers to inspect the aircraft and attach a wire strap to the nose gear. This plan was cancelled due to heavy swells causing OIL HARRIER to surge

excessively making diving operations very dangerous. Trouble with the Nydac line developed as the outer casing of the line chaffed through in several places. The aircraft was lowered to 300 feet in preparation for towing to shallower water. As soon as towing commenced the Nydac lift line parted, and the aircraft settled to the bottom in an upright position in nearly 1500 feet of water.

On the 27th of October a second lift attempt was made after NR-1 again secured a line to the choker. This time a 10-inch-circumference nylon line was utilized. OIL HARRIER's powerful winch again began to grind and the aircraft was hoisted to 100 feet below the surface. Once again the surge of OIL HARRIER made diving impossible. The A/C was lowered to approximately 400 feet and HARRIER commenced to head for shallow water. Suddenly the choker parted, once again the F-14 fell, this time on its third trip to the bottom.

Resupply requirements and weather combined to force the ships to return to port. CONSTRUCTOR and OIL HARRIER proceeded to Kirkwall. U. S. Commander Eastern Atlantic had contracted for three additional vessels, the TARUS, a West German salvage ship; the BOSTON HALIFAX, a British trawler; and the TWYFORD, a West German work ship to join in the effort.

In the meantime, the NR-1 diligently searched the bottom for the Phoenix missile and on 30 October the elusive weapon was located. NR-1 photographed the weapon, recovered it, and surfaced, passing its precious cargo to SUNBIRD.

On 4 November TARUS, BOSTON HALIFAX, TWYFORD and SHAKORI departed Kirkwall and proceeded to the site of the F-14. HALIFAX, equipped with a steel trawl net, began dragging in an attempt to snag the F-14. On the third pass the F-14 was in the net but BOSTON HALIFAX was not successful in lifting the aircraft. Neither the net or BOSTON HALIFAX's winches proved strong enough to lift the fighter. The tactics changed and the TARUS and TWYFORD attempted to snag the aircraft by dragging a 37 millimeter high strength wire between the ships. This ancient technique was successful and TWYFORD passed her end of the wire to TARUS to allow her to tow the F-14 to shallow water.

After towing for 21 hours and just passing the west end of Orkney Island lighthouse, the aircraft struck a submerged ledge at 165 feet. The jolt broke loose the starboard main landing gear of the aircraft. A side scan search relocated the aircraft and TARUS moored over the F-14 and an observation bell was lowered. Inspection found the aircraft inverted, the wing broken, half of both horizontal stabilizers were missing; the vertical stabilizer embedded in the bottom, but the fuselage mainly intact.

Divers went over the side with SCUBA gear, but were unable to attach a lift line. Surface supplied divers were utilized and were successful in attaching a heavy lift wire to the nose landing gear.

Finally, at 1430 of the 11th of November, the F-14 tomcat gave up and broke clear of the water.

Two metal smiths and a painter worked feverishly and soon the F-14 was airborne.

A fascinating search and salvage effort was closed. It was an effort unparalleled in the annals of sea history. A great deal of skill, determination and dedication went into this effort and proved that with sufficient tenacity and dogged persistence even "Murphy's Law" can be overcome.